MyHealthToday: Helping patients with their healthschedule using a 24-hour clock visualization

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***Abstract*—We propose a variation on the 24-hour clock visualization to represent daily health schedules. The area inside the clock is used to display a graph network which helps patients explore and understand the rationale for each health-related scheduled task, such as taking medication. We investigate whether this visualization can be leveraged to increase patient comprehension of personal health schedules. Two low and one high-fidelity prototype have been designed and evaluated. Participants in our study included both general practitioners and patients. Results are promising and indicate that our visualization can be an effective means to explore and understand health schedules. Moreover, our results suggest there is an actual need for visual exploration of health schedules. Finally, participants perceive that our proof-of-concept provides useful feedback and can help both patients and physicians to discuss and explore health schedules.**

I. Introduction

Giving control to patients has gained increased interest in the healthcare informatics domain [5]. However, because maintaining adequate health care typically entails many different tasks, it is often useful for patients to keep a schedule to assist them with fitting health routines into their daily lives. This can become burdensome, especially in the context of today's typical busy lifestyle. For example, consider the following simple health schedule: "*take medication in the morning before breakfast, doctor's appointment at 2 pm, measure blood glucose every four hours starting at 10 am and walk for 10 minutes in the afternoon.*" Even this simple plan can be challenging to remember and to keep up with. Moreover, some patients suffer from various conditions simultaneously and have numerous health-related tasks to perform each day. Hence, a Personal Health Record (PHR) provides an opportunity to 1) help patients remember and 2) show a summary of their tasks. Furthermore, patients "*with complex, chronic conditions, often with more than one long term condition, are most likely to find a PHR useful and have the most to gain in the first instance*" [6].

Health information is complex and not always easy to communicate. Moreover, research shows that often not only the health condition, but also health literacy tends to get worse with age [14]. To address these issues, we argue, based on examples in doctors' electronic health record systems [9], that PHR systems can also be augmented with information visualizations to help patients understand, explore and explain their personal health schedules.

Through an iterative design process involving both HCI and health domain professionals (two medical software experts, two legal experts, two medical researchers, one general practitioner), we developed a visualization called MyHealthToday that augments patients in their capability to understand personal health schedules. MyHealthToday is developed as a proof-of-concept that makes patient health schedules visible through a 24-hour clock, providing concise overviews of health schedules and the rationale for each task.

The contribution of this paper is the design and implementation of a visualization that represents patients' daily health schedules. We present the evaluation results of the perceived usefulness of our design with in total 25 participants and identify both weaknesses and benefits of our approach. Results indicate that our visualization can help to increase patient comprehension of health schedules.

II. Related Work

To give insight into the challenges of using traditional schedules in the domain of healthcare, we provide background and position our work within related health-oriented visualizations.

A. Personal Health Records

PHRs can be used as a tool to manage illness, but also in maintaining health and wellness [23]. Siek et al.'s [26] also used a 24-hour clock interface in their Colorado Care Tablet prototypes. However, some of their older participants struggled to determine the time on a 24-hour clock prototype. Nevertheless, their expert review panel "*reminded [them] that for scheduling medications, people may have to schedule medications throughout a 24-h period*" and a 24-hour clock can present an entire day in one view.

Additionally, adherence to health schedules is a problem. For example, people often forget, or refuse, to take their medication for various reasons [12]. They might feel they are unhealthy and unnecessary [25]. Several HCI researchers have explored opportunities to use technology to support patients. Medication reminders/helpers are well known assistive technologies. It is shown that dosage simplification, counseling, reminders, follow-up, supervised self-monitoring, and feedback have the largest positive effect [16]. Medication apps represent a possible strategy to assist non-adherent people [8]. MyHealthToday could be integrated in such a medication app or PHR as it

aims to empower patients by providing transparent and open information. Providing patients with a clear schedule and more information on why they must take these pills can support decision-making and adherence [13].

B. Schedules

It is not straightforward to fit a busy day schedule on a smaller screen such as a tablet. Although Dalgaard et al [7] suggest "*that a calendar interface for medication management should be designed to provide an overview of medication intake at a glance (limiting the scrolling as much as possible)*", traditional calendar applications fail to deliver a glanceable overview when tasks are divided over 24 hours. Google's mobile calendar application tries to alleviate this problem with their '*schedule view*' [17] that visualizes all items vertically without showing the 'empty' hours in between. Nevertheless, using this approach it is harder to pre-attentively see at what time an item is scheduled. Besides position, color is often used to differentiate between different categories such as work, commute and leisure. However, due to the typical calendar layout, there are no other variables to simultaneously show additional information.

Buzzo and Merendino [4] claim the traditional grid calendar and its assumptions "*make the ongoing usage of the traditional metaphor inherently calendar-orientated rather than user-orientated.*" Furthermore, although a patient's health schedule can sometimes be the starting point of a patient-caregiver consultation, traditional calendars are not designed as a collaborative decision tool. However, shared decision making is key to empower patients [18]. Considerable research has been carried out concerning health schedules [15].

C. Time Series and Circular Health Visualizations

A large body of work has been devoted to the visualization of time series [1]. In this paper, we propose to use a 24-hour clock visualization and use the area inside the clock to display a graph network which helps the patient understand, explore and explain the rationale for each scheduled task. The idea of using a clock visualization to show upcoming events is also applied in SpiraClock [10]. Clock visualizations range from simple low-fidelity mockups [28] to advanced radial displays as applied in Zhao et al.'s [29] multipurpose time-series exploration tool called KronoMiner.

Pagno and Nedel [21] also use a clock visualization that is composed of two areas showing different information on the same context. The outer part of the clock shows the number of steps taken by the user and displays appointments by showing a thicker margin and a darker color tone on each slice. The inner part contains bubbles representing the amount of time spent on different projects. The bubbles have distinct colors that make it easier to recognize the same task in different days.

III. Design

A. Study Design

We followed an iterative approach to the development of MyHealthToday. This approach allowed us to gradually improve and validate the design of the visualization. The development of MyHealthToday went through three main studies as presented in Figure 1. We presented an initial, low-fidelity design at a consortium with representatives of different stakeholders including two medical software experts, two legal experts, and two medical researchers (Study 1: Concept). Then we refined the original design and discussed the resulting visualization with an expert general practitioner at the Academic Center for General Practice in Leuven to test for medical relevance (Study 2: Medical Relevance). Finally, after integrating the general practitioner's feedback into MyHealthToday's design, the visualization was implemented using the d3.js library [2] and evaluated as a high-fidelity proof-of-concept with 25 participants (Study 3: Final Evaluation). The details and results of this final user study are presented in the next section. In this section, we present results of Study 1 and Study 2, as well as design improvements that were made based on observations of these initial studies.

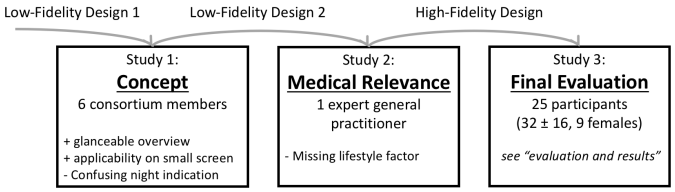

Fig. 1. Timeline that shows the participants in each iteration and the identified attention points. The design used in each study is shown on the arrows.

B. Study 1: Concept

A main consideration for the design of MyHealthToday was the selection of the displayed information, to maximize the amount of information available to users, while avoiding an overwhelming view with too much visual clutter. The daily schedule of the patient is visualized as a 24-hour clock to show a concise overview of one day. Colored arc-segments indicate between which hours patients have an item scheduled. Three different colors represent the type of activity. In this prototype blue indicates the patient should take medication or vitamins, green indicates the patient should measure a certain parameter, such as blood sugar values, and purple indicates the patient has a meeting, for example with a health care professional.

Inside the clock area two concentric circles are drawn (Figure 2C&D) to represent the patient's health status: the most inner circle is used for allergies, such as hay fever, and the second circle stands for health conditions, such as diabetes. A node is drawn on each corresponding circle (Figure 2B) for each registered condition of the patient (e.g. depression). The size of each node visualizes the severity of each condition. Moreover, each task in the schedule is connected to the corresponding condition to visualize the rationale for each scheduled assignment. Finally, a light-gray background arc (Figure 2A) indicates the suggested sleep duration.

Both the glanceable overview and the applicability on smaller screens were perceived well by the consortium stakeholders. The glanceable overview was praised because a full day, including time slots during the night, are immediately visible in

one view. Thanks to the 24-hour clock format, users can easily create a perceptual image when and why they should do a task. The so-called mobile-first approach was primarily praised by two medical software suppliers. To verify the importance of the mobile-first approach, participants were asked in the final evaluation to indicate on which device they would prefer to use MyHealthToday. One concern with the initial design was that users might think elements inside the gray arc area are only relevant during the night. For example, an episode could have been drawn inside the gray arc area while it has nothing to do with the night slot. This is changed in the next prototype, where instead of a full arc segment only a gray banner (Figure 2A) is shown behind the advised sleep hours. The role of the legal experts was to validate compliance with the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679) and to verify whether ethical approval was needed for this study. As no real medical data was used in this exploratory study, there were no issues.

C. Study 2: Medical Relevance

The second low-fidelity design was discussed at the Academic Center for General Practice in Leuven with an expert general practitioner to test for medical relevance. The design of MyHealthToday was well received. However, as the expert indicated, general practitioners can also advise their patients to perform more health-related tasks, the so-called lifestyle factors. For example, perform 12 wall slide exercises. Therefore, an extra category was added to visualize these factors (Figure 2F).

Additional feedback was to add a general health score. However, this is out of scope of this calendar application. Indeed, MyHealthToday is a visualization of registered patient data and the necessary measurements to calculate health scores are currently not registered in the electronic health record of the patient. Furthermore, this would require patients to register how they performed a task. Nevertheless, this could be an extension of our visualization.

Based on the feedback from these two initial studies, a high-fidelity, proof-of-concept was built as presented in Figure 2. This prototype was built using modern web technologies, such as the d3.js library [2].

IV. User Study

A. Evaluation setup

To assess the added value of MyHealthToday, we have analyzed the way participants explore and use the visualization when asked to perform a task-based scenario. An evaluation protocol was prepared as recommended by Taylor et al. [27]. Participants were not recorded since it could make them 1) feel uncomfortable [27]; 2) unwilling to discuss certain topics [20]; and 3) hold back information [20]. Participants were asked to perform six tasks during individual face-to-face interviews. These tasks were discussed beforehand at the Academic Center for General Practice in Leuven to cover relevant health tasks. The participants did not receive any information nor a tutorial

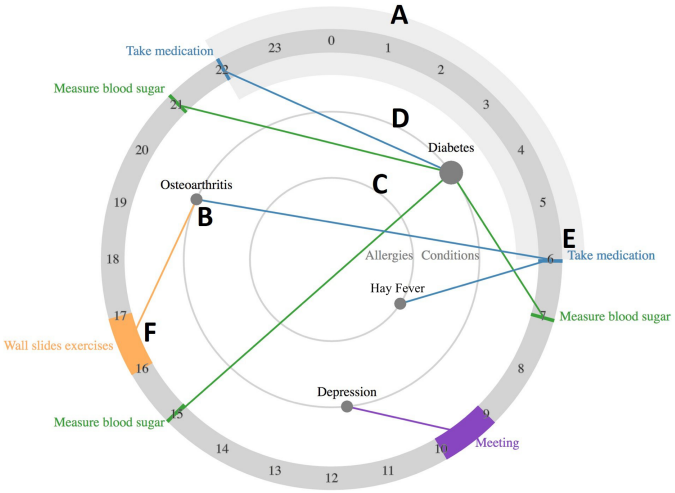

Fig. 2. The high-fidelity prototype that was used during the final evaluation. The major change compared is the gray banner (A) instead of the gray arc segment to indicate the suggested sleep period. Allergies and conditions are drawn as nodes (B) on the allergy (C) and condition (D) circle respectively. Tasks are drawn at the start-time (E) or at the corresponding time range (F). Note the additional category (F) to visualize physiotherapy/life-style tasks.

when the visualization was shown to them on a 10-inch tablet.

1) What do you have to do today?
2) Why do you have to measure blood sugar values at 3 pm?
3) What do you have to do between 9 am and 10 am?
4) What are your allergies according to the visualization?
5) What is your advised bed time?
6) What is your advised sleep duration?

B. Measurements and Data Collection

The following data was measured during the evaluation:

1) *Qualitative data*: During these interviews, the concurrent Think-Aloud Protocol [19] was applied to let participants explain what they think when seeing the visualizations. In this way, it can be tested whether participants understand the message that the visualization tries to convey.
2) *Number of mistakes*: Each time a participant performed a task, we register the number of mistakes made. Furthermore, the reason for each mistake was documented.
3) *Usability and perceived usefulness*: Besides the six tasks, participants were asked to answer two open questions on the design:
   a) Before the task-based scenario participants were asked to describe what they saw when the visualization was presented to them for the first time.
   b) After the task-based scenario participants were asked whether there is additional information they wanted to see. This information is dependent on each participant's unique condition and might expose additional variables.

After the task-based scenario, participants were requested to respond to a questionnaire with six perceived usefulness questions based on the work of O'Leary et al. [20] and ten System Usability Scale (SUS) [3] questions. In addition, we inquired about the perceived usefulness to support dialogue, as shared decision making is a key challenge to empower patients

as described in Section II. A health schedule is often a starting point for a discussion with a general practitioner. Therefore, we also asked if participants would perceive the visualization as helpful during a meeting with their general practitioner using three five-point Likert items.

C. Participants

Participants were found through a call for participation published on personal websites. We did not impose any inclusion criteria. In total 25 participants (16 males and 9 females) who were on average 32 ($\pm$ 16.3) years old participated. Eleven participants needed to take daily medication, and five participants indicated they prepared a consultation with their general practitioner. Moreover, seven participants mentioned they often forget to ask questions to their general practitioner. The same schedule was shown to all participants. Participation was voluntary and not compensated. Each participant could only participate once. Each session took approximately 30 minutes.

D. Tasked-Based Scenario

All participants finished most tasks and few mistakes were made. Figure 2 shows the visualization as it was shown to participants.

Task 1) "*What do you have to do today?*" could be solved by going over all the elements on the outer circle of the 24-hour clock. This task was successfully completed by all participants. No mistakes were made.

Task 2) "*Why do you have to measure your blood sugar values at 3 pm?*" could be solved by following the line that connected the 3 pm event with Diabetes. It was correctly answered by 24 out of 25 participants. Only one participant made a mistake. For this participant, the line connecting the assignment with diabetes was not clear.

Task 3) "*What do you have to do between 9 am and 10 am?*" was the hardest task for our participants: only 21 out of 25 participants could correctly answer this question. Four participants were confused about the word 'meeting".

Task 4) "*What are your allergies according to the visualization?*" had similar issues as Task 3. The task could be solved by listing all elements on the most inner circle, which is the circle that groups the allergies. 22 out of our 25 participants answered correctly.

Task 5) "*What is your advised bed time?*" and Task 6) "*What is your advised sleep duration*" were answered without mistakes. The gray banner indicates the advised sleep period. However, this only became clear to 22 out of 25 participants when they were asked to complete Task 5.

In general, most participants could provide correct answers to the different tasks. Some issues were identified related to word usage. For example, the word 'meeting' (consultation) was not clear in Task 3.

E. Usability Questions

The system scored an average SUS score of 81.5 ($\pm$ 12). This score ranks MyHealthToday in the top 10%, and gives it an A grade (above 80.3) [24]. The first question "*I think that I would like to use this system frequently*" was agreed upon by 19 out of 25 participants. However, qualitative feedback indicated that participants would only use the system when they actually have health-related tasks scheduled. This high usability score is also reflected on the ease with which participants answered the questions.

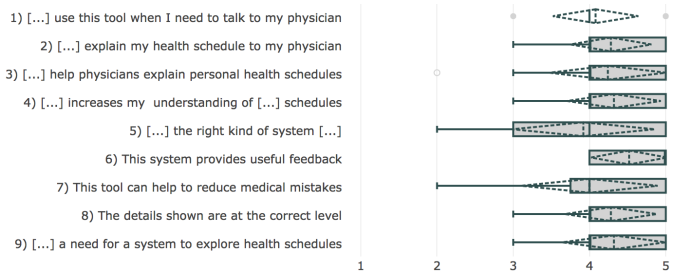

Fig. 3. Answers on the perceived usefulness questionnaire. Answers range from 1 (strongly disagree) to 5 (strongly agree). Dotted lines indicate the mean and standard deviations. The first three questions ask about dialogue supporting questions.

F. Perceived Usefulness Questions

The distribution of the answers is shown in Figure 3. The first three questions inquire about the perceived usefulness to support the dialogue between the patient and a general practitioner.

Question 1) "*I would like to use this tool when I need to talk to my physician*" was agreed upon by 22 out of 25 participants. They indicated they would indeed like to use MyHealthToday when they actually do need to talk to their physician. Three participants answered neutral, of which one participant indicated he already knew his schedule by heart.

Question 2) "*This tool helps me to explain my health schedule to my physician*" was consistently perceived high by 24 out of 25 participants. One participant indicated neutral but did not provide the reason for doing so.

Question 3) "*This tool can help physicians explain personal health schedules*" was agreed upon by 22 out of 25 participants. One older participant disagreed as he believed his physician was already capable of explaining health schedules.

After these three dialogue-related questions, six questions inquired about the general perceived usefulness.

Question 4) "*This tool increases my understanding of my personal health schedule*" was positively perceived by 23 out of 25 participants. Two participants answered neutral as they indicated that they were already aware of their own health schedule using paper calendars.

Question 5) "*This system is the right kind of system to visualize personal health schedules*" scored relatively low since only 17 out of 25 participants agreed. The eight other participants did not think it was 'the' right kind of tool, but rather 'a' suitable tool. However, two participants expressed their interest in using MyHealthToday to prepare their pill box.

Question 6) "*This system provides useful feedback*" was answered positively by all 25 participants. None of the participants manifested the need for more or less information

than the one already represented in MyHealthToday, nor could anyone think of personal examples that could not be visualized.

Question 7) "*This tool can help to reduce medical mistakes*" was perceived well by 19 out of 25 participants. They agreed that by visualizing an overview of all health-related assignments, inconsistencies can easily be discovered. Four participants answered neutral without indicating a reason and two participants disagreed. These two participants indicated that it can expose potential medical errors, but not reduce them.

Question 8) "*The details shown are at the correct level*" was perceived well by 23 out of 25 participants. Two participants answered neutral as they would like to obtain more information when they click on a certain element in the visualization. Furthermore, three participants indicated they prefer to see whether medication should be taken before/during/after a meal.

Question 9) "*There is a need for a system to explore health schedules*" was perceived well by 22 out of 25 participants. Those who answered neutral stated that they were happy with their existing calendar application, and that they can remember why they need to do each assignment.

Finally, as described in Section III participants were asked on which devices they would like to use MyHealthToday in a multiple answer question: 56% listed smartphone, 48% desktop, 32% tablet, and 4% smartwatch, TV, and paper.

V. Discussion

A. MyHealthToday as a tool to explore health schedules

In all three studies, participants primarily raised usability issues, such as the arc segment that was replaced by the banner to represent sleep periods. Most important is that none of our participants experienced, nor expressed [26], issues with the 24-hour clock visualization as implemented in MyHealthToday. However, MyHealthToday it is not a real 'clock' as no hands are shown and, and in contrast to Siek et al. [26] the area inside the clock is not empty. Second, the banner shows the night period. This can create awareness that the design is not a regular 12-hour clock.

MyHealthToday primarily focuses on informing patients on when and why they should do certain tasks, such as taking medication. No distinction between 'real' medication and vitamins or supplements is made. But, as Palen et al [22] mention, it is important to be aware of all the pills taken by the patient to detect contra-indications. Nonetheless, whenever a general practitioner wants to explicitly differentiate between medication and supplements, an additional category can be added by using another color.

B. Improvements

Although 22 out of 25 participants did not immediately understand the meaning of the gray banner to visualize recommended sleep periods, 24 participants indicated that, once its meaning was understood, the banner was an appropriate representation (see Figure 2A). No suitable alternatives were suggested by our participants. A potential solution to this issue would be to use an additional day/night icon as a visual clue. Furthermore, meal icons should be integrated to indicate if the user should do a certain task before/during/after a meal. Similarly, it may be useful to indicate different time periods of a typical day, such as free time, work, and commute.

The conditions circle was not clear for seven out of 25 participants, although everyone could deduce the meaning from the diseases/diagnoses shown in the visualization. However, the word 'meeting', which was used to show a consultation, was confusing to 13 out of 25 participants. In this case, four participants could not deduce the meaning from the context. The use of synonyms to the visualization may alleviate this problem. For example, to tag the 'meeting' event with synonyms like 'appointment' or 'consultation' might contribute to clarify the nature of the event. Finally, two participants mentioned the current time should be highlighted. Now, users should first check the current time elsewhere and find this time in MyHealthToday to see which is the next scheduled task.

MyHealthToday, in its current version, can only assign health tasks to a certain time slot by the general practitioner. However, some activities, such as walking for 30 minutes, might not be limited to a certain time slot. The visualization could be augmented with a variable to show how flexible the time slot is. Additional extensions proposed by our participants include a closer link to the electronic health record. For example, health information can be shown when a user clicks on a node. Moreover, showing validated health information can increase patients' health literacy [11]. Another participant suggested an option to make an appointment directly from MyHealthToday. Finally, as this was only a proof-of-concept a limited data set was visualized. Future work should explore scalability and readability when patients have more health conditions.

C. Limitations

Three limitations of this exploratory study should be acknowledged. First, since this work describes a proof-of-concept design, it is not evaluated 'in the wild' and thus only the perceived usefulness could be measured. Second, the data visualized was preloaded and thus not personal. However, the data was discussed at the Academic Center for General Practice to test relevance. Third, there should also have been a question that measured if users understood the size of each node. However, four participants asked - correctly - if the size represented the severity. Notwithstanding these limitations, we were able to demonstrate the perceived usefulness of MyHealthToday, and to identify strengths and weaknesses.

VI. Conclusion and Future Work

MyHealthToday was designed following an iterative approach and evaluated in each iteration. It was evaluated in the final iteration with 25 participants. The perceived usefulness questionnaire (Figure 3) shows that MyHealthToday might help both patients and physicians to discuss and explore health schedules (Questions 2 & 3); that it shows useful feedback (Question 6); and that participants think there is an actual need for a visual system to explore health schedules (Question 9). Moreover, it is interesting to note that positive qualitative feedback was received during the study.

Overall, the results of this study indicate MyHealthToday is perceived to be able to help increase patient comprehension of

personal health schedules. However, as this is an exploratory study, further research is needed before claims can be made on the actual impact on patient comprehension. On the other hand, the visualization is able to show a glanceable overview of a realistic health schedule that easily fits on small screens.

The visualization has additional variables compared to a traditional calendar that can be used to leverage the amount of information conveyed: nodes to visualize the rationale, lines to connect each task with a node, the size of the node, the inner circles, and banners. Furthermore, icons can be added for readability of additional information. In general, participants were able to give correct answers to different types of questions and were positive about the perceived utility of the visualization in their daily lives.

In the future, we will address the limitations identified in this work and integrate the lessons learned. The visualization should also be enhanced with other interactions, such as selecting, panning, zooming, and in different platforms, like smartwatches or tablets.

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